PATENT
Attorney Docket No. 502469
Client Reference No. 03045

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of:

Atul Kelkar et al.

Application No.: 10/731,742

Filed: December 9, 2003

For: METHOD AND SYSTEM TO PERFORM ENERGY-EXTRACTION BASED ACTIVE NOISE CONTROL

Art Unit: 2123

Examiner: Juan Carlos Ochoa

APPELLANTS' APPEAL BRIEF

Mail Stop Appeal Brief - Patents
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Dear Sir:

In support of the Appeal from the final rejection dated May 23, 2008, Appellants now submit their Appeal Brief required by 37 C.F.R. §41.37.

CERTIFICATE OF TRANSMISSION UNDER 37 CFR 1.8			
I hereby certify that this Appeal Brief and all accompanying documents are, on the date indicated below, ☒ being transmitted to the United States Patent and Trademark Office via the Electronic Filing System.			
Name (Print/Type)	A. Locke		
Signature	/A. Locke/	*Date*	October 21, 2008

(1) Real Party In Interest

The real parties in interest of the patent application that is the subject of this appeal are Iowa State University Research Foundation, Inc. and the United States of America as represented by The Administrator of the National Aeronautics and Space Administration (NASA), the assignees of the entire right, title and interest.

It is to be noted that this invention was made in part with Government support under Grant number NCC-1-01039 awarded by NASA and Grant Numbers 0196198 and 0301740 awarded by the NSF. The Government has rights in this invention.

(2) Related Appeals and Interferences

The Appellants previously filed an Appeal Brief in this case on March 10, 2008. In response to the Appellants' Appeal Brief, the Examiner reopened prosecution in an Action dated May 23, 2008. This new Appeal Brief is in response to the Examiner's Action reopening prosecution.

(3) Status of Claims

Claims 1 and 3-16 are currently pending in this application. Claims 1 and 3-16 stand rejected and are at issue herein and being appealed. Claims 3-7 are objected to as depending on rejected base claim 1. Claims 8, 9 and 16 are indicated as allowable but newly rejected under 35 U.S.C. § 112, but indicated as allowable if rewritten to overcome the indefiniteness rejection. Thus, claims 1 and 3-16 are at issue herein and being appealed.

(4) Status of Amendments

All Amendments have been entered for purposes of appeal.

(5) Summary of Claimed Subject Matter

The present invention relates to energy extraction to actively control noise.

A concise explanation of the subject matter in each of the independent claims involved in the appeal is set forth below. Line number references noted below have been determined by counting only the lines of text of the cited paragraph as originally filed.

Claim 1

A method to design a feedback controller for extracting acoustic energy and structural energy in an acoustic enclosure is provided. The method comprises the steps of obtaining a continuous-time multi-input multi-output state-space mathematical model of the acoustic enclosure (¶ [0030], lines 3-5); designing compensation to render the mathematical model passive in accordance with mathematical system theory if the mathematical model is not passive, thereby forming a compensated system that is passive (¶ [0030], lines 6-7); checking passivity of the compensated system (¶ [0031], line 1); and designing a passivity-based controller that extracts the acoustic energy and the structural energy such that a resulting closed-loop response provides a desired noise reduction(¶ [0031, lines 5-9; ¶ [0026], lines 7-8).

Claim 8

A method to design a feedback controller for extracting acoustic energy and structural energy in an acoustic enclosure comprising the step of obtaining a continuous-time multi-input multi-output state-space mathematical model of the acoustic enclosure (¶ [0030], lines 3-5). The method also includes the step of designing compensation to render the mathematical model passive in accordance with mathematical system theory if the mathematical model is not passive, thereby forming a compensated system that is passive (¶ [0030], lines 6-7). In addition, the method includes checking passivity of the compensated system (¶ [0031], line 1). The method includes designing a passivity-based controller that extracts at least one of acoustic energy or structural energy such that a resulting closed-loop response provides a desired noise reduction (¶ [0031, lines 5-9; ¶ [0026], lines 7-8). The step of designing compensation comprises the step of performing sensor blending if there are redundant sensors.

Claim 9

A method to design a feedback controller for extracting acoustic energy and structural energy in an acoustic enclosure comprising the steps of obtaining a continuous-time multi-input multi-output state-space mathematical model of the acoustic enclosure (¶ [0030], lines 3-5); designing compensation to render the mathematical model passive in accordance with mathematical system theory if the mathematical model is not passive, thereby forming a compensated system that is passive(¶ [0030], lines 6-7); checking passivity of the

compensated system (¶ [0031], line 1); designing a passivity-based controller that extracts at least one of acoustic energy or structural energy such that a resulting closed-loop response provides a desired noise reduction (¶ [0031, lines 5-9; ¶ [0026], lines 7-8); and wherein the step of designing compensation comprises the step of performing control allocation if there are redundant actuators.

Claim 16

A method to design a feedback controller for extracting acoustic energy and structural energy in an acoustic enclosure. The method comprises the step of obtaining a continuous-time multi-input multi-output state-space mathematical model of the acoustic enclosure (¶ [0030], lines 3-5). The method also includes the step of designing compensation to render the mathematical model passive in accordance with mathematical system theory if the mathematical model is not passive, thereby forming a compensated system that is passive (¶ [0030], lines 6-7). The method includes checking passivity of the compensated system (¶ [0031], line 1). The method includes designing a passivity-based controller that extracts at least one of acoustic energy or structural energy such that a resulting closed-loop response provides a desired noise reduction (¶ [0031, lines 5-9; ¶ [0026], lines 7-8). The step of designing compensation comprises the steps of designing a constant gain feed-forward compensation to render the compensated system minimum-phase; and rendering the compensated system positive-real by one of sensor-blending and control allocation.

(6) Grounds of Rejection

The issue presented in this appeal is the following:

I. Are claims 1, 8, 9 and 16, and corresponding dependent claims, indefinite pursuant to 35 U.S.C. § 112, second paragraph?

II. Does the combination of Kelkar and Joshi, entitled "Robust Passification And Control of Non-Passive Systems" (Kelkar hereinafter) taken in view of Son et al. entitled "Stabilization of Linear Systems Via Low-Order Dynamic Output Feedback: A Passification Approach" (Son hereinafter) and in view of H.R. Pota and A.G. Kelkar, Modelling and Control of Acoustic Ducts (Pota hereinafter) and in further view of Pota, Reza Moheimani and Smith (Pota (2) hereinafter) enable and teach or

suggest the invention as claimed in claims 1 and 10-15 presenting a *prima facie* case of obviousness for claims 1 and 10-15 under 35 U.S.C. § 103(a)?

(7) Argument

I. CLAIMS 1, 8, 9 AND 16 DISTINCTLY CLAIM AND PARTICULARLY POINT OUT THE APPELLANTS' INVENTION

The Examiner has rejected claims 1 and 3-16 under 35 U.S.C. § 112, second paragraph, as being indefinite for failing to particularly point out and distinctly claiming the subject matter which the Appellants regard as the invention. The Appellants must traverse this grounds of rejection and respectfully request the Board to overturn the rejection.

The Appellants would first like to note that they are extremely shocked to see this rejection at this significantly late stage in prosecution. This new rejection is the epitome of piecemeal prosecution that is expressly admonished by MPEP § 707.07(g). Further, compounding the absurdity of the timing of this rejection is that this is the fourth Action on the merits for this case. The Examiner is presumed to have reviewed these claims three (3) previous times and found these claims to be entirely definite.

Further compounding the absurdity of the timing of the rejection is the rejection itself. The Examiner was required to ignore fundamental principals of claim interpretation to remotely generate an argument that this claim is indefinite.

The Examiner takes objection to the claims as they all relate to "a method to design a feedback controller" that includes the step of "designing a passivity-based controller." The Examiner is apparently objecting to a perceived breadth of the language "designing a passivity-based controller" by stating that "Examiner notes that a passivity-based controller may be series, feed-forward, feedback, hybrid, or other type . . .." Office Action dated May 23, 2008, Pg. 4, § 9, Lines 1-4.

The first problem with this analysis is that the Examiner relies on a section of the pending application for importing the perceived breadth to the claim limitation that does not even apply to the objected to claim limitation. The cited section of the application does not relate to the step of "designing a passivity-based controller." Instead, a review of the cited to language quoted by the Examiner makes clear that the cited language relates to the step of "designing <u>a compensation</u> to render the mathematical model passive in accordance with mathematical system theory." As stated in quoted step, this step relates to compensation for the mathematical model. The application makes clear that this "compensation may be series,

feed-forward, feedback, hybrid, etc." Thus, this section is not applicable to the step of "designing a passivity-based controller." As such, the Examiner has imported breadth into a claim limitation by citing to a section of the application that is not relevant to that limitation. For this reason, the Examiner's rejection makes no sense and has set forth no reason as to why the objected to language is indefinite.

With that being said, even assuming *arguendo* that a "passivity-based controller may be series, feed-forward, feedback, hybrid, or other" as suggested by the Examiner, such broad disclosure in the specification does not render the instant claims indefinite. It is axiomatic in patent law and claim interpretation that a claim must be read as a whole rather than element by element. See also MPEP § 2173 stating:

> In reviewing a claim for compliance with 35 U.S.C. 112, second paragraph, the examiner must consider the claim as a whole to determine whether the claim apprises one of ordinary skill in the art of its scope and, therefore, serves the notice function required by 35 U.S.C. 112, second paragraph, by providing clear warning to others as to what constitutes infringement of the patent. See, e.g., *Solomon v. Kimberly-Clark Corp.*, 216 F.3d 1372, 1379, 55 USPQ2d 1279, 1283 (Fed. Cir. 2000). See also *In re Larsen*, No. 01-1092 (Fed. Cir. May 9, 2001) (unpublished) (The preamble of the *Larsen* claim recited only a hanger and a loop but the body of the claim positively recited a linear member. The court observed that **<u>the totality of all the limitations of the claim and their interaction with each other must be considered to ascertain the inventor's contribution to the art</u>**[emphasis added]. Upon review of the claim in its entirety, the court concluded that the claim at issue apprises one of ordinary skill in the art of its scope and, therefore, serves the notice function required by 35 U.S.C. 112 paragraph 2.). >See also *Metabolite Labs., Inc. v. Lab. Corp. of Am. Holdings*, 370 F.3d 1354, 1366, 71 USPQ2d 1081, 1089 (Fed. Cir. 2004) ("The requirement to 'distinctly' claim means that the claim must have a meaning discernible to one of ordinary skill in the art when construed according to correct principles...**<u>Only when a claim remains insolubly ambiguous without a discernible meaning after all reasonable attempts at construction must a court declare it indefinite</u>** [emphasis added]. MPEP 2173.02

Therefore, the objected to language "designing a passivity-based controller" must be read in context of the claim as a whole and there can be no discernible meaning to the claim to render the claim indefinite. The Examiner's failure to follow these principles in construing the claims is clear legal error on its face.

Thus, the alleged broad recitation of the step of "designing a passivity-based controller" must be read in context of the claim as a whole and particular the preamble limitation relating to the "method to design a feedback controller." When one follows the proper rules for claim interpretation, it becomes clear that the objected to language is definite

in context of the entire claim. Clearly, when reading the claim as a whole, the objected to language is definite and would become limited to the types of "designing a passivity-based controller" that is consistent with that earlier recitation to "design a feedback controller." Thus, the passivity-based controller of the claimed step would be limited to that type of a controller that is consistent with a feedback controller. As such, even assuming the Examiner's interpretation of the broad scope of "designing a passivity-based controller," the claim is clearly definite when viewed as a whole and is not indefinite such that there is no discernible meaning to the claim.

The Board is respectfully solicited to overturn this rejection and indicate the allowability of claims 1 and 3-16.

II. THE PROPOSED COMBINATION OF KELKAR IN VIEW OF SON IN VIEW OF POTA AND IN FURTHER VIEW OF POTA (2) FAILS TO ENABLE AS WELL AS TO MAKE OBVIOUS THE INVENTION AS CLAIMED IN CLAIMS 1 AND 10-15

There must be some articulated reasoning with some rational underpinning to support the legal conclusion of obviousness. *In re Kahn*, 441 F.3d 977, 988, 78 USPQ2d 1329, 1336 (Fed. Cir. 2006). See also *KSR v. Teleflex*, 82 USPQ2d at 1396 (citing to Federal Circuit statement with approval). In other words, the key to finding a *prima facie* case of obviousness under 35 U.S.C. § 103 is the clear articulation of the reason(s) why the claimed invention would have been obvious. See MPEP 2143.

As the Appellants' prior Appeal Brief dated March 10, 2008 and the arguments presented therein are already part of the record and the Board is presumed to have considered those arguments, the Appellants will not regurgitate the arguments regarding the deficiencies of the combination of Kelkar, Son and Pota. However, those arguments are expressly renewed and incorporated into this Appeal Brief.

As successfully argued in the previous Appeal Brief, the combination of Kelkar, Son and Pota fails to render obvious claim 1 as the combination entirely failed to address the step of "designing a passivity-based controller that extracts acoustic energy **and** structural energy." Kelkar and Son fail to address anything regarding the type of system that their control theory is applied to and therefore make no discussion of extracting acoustic and/or structural energy from an acoustic enclosure. Thus, the Examiner relied on Pota, for at least,

as teaching a controller relating to extracting acoustic energy **and** structural energy. However, the previous arguments successfully pointed out to the Examiner that Pota fails to relate to extraction of structural energy from an acoustic enclosure and that Pota only relates to extracting acoustic energy. More particularly, in the most recent Office Action, the Examiner states "Pota does not expressly disclose a passivity-based controller that extracts structural vibration." Page 8, § 22, Lines 3-4.

As the Appellants' previous arguments overcame the rejection based on those three references, the Examiner has issued new grounds of rejection adding a fourth reference Pota (2) in formulating his case of obviousness of claims 1 and 10-15.

With that background, the new ground of rejection will be addressed.

When formulating a rejection of a claim over prior art, the reference or combination of references must be enabling. MPEP 2121. As will be more fully discussed below, the combination of Kelkar, Son, Pota and Pota (2), if they even disclose all the elements of the invention of claims 1 and 10-15, fails to enable such an invention.

The Examiner relies on Pota (2) for teaching "a passivity-based controller that extracts structural vibration such that a resulting closed-loop response provides a desired noise reduction. (see page 631, col. 2, last paragraph)." Office Action dated May 23, 2008, Pg. 8, § 23, Lines 1-3.

Initially, the Appellants would like to address the factual findings of the section relied upon by the Examiner. The actual section relied upon by the Examiner makes no reference to the actual type of controller that was used and found successful. The relied upon passage states:

> This paper proposes a direct method to "push" down the resonant peaks using high-Q resonant circuits shown in Figure 3. This method has been experimentally validated on a cantilever beam.

First, this passage makes no reference to or suggestion relating to "passivity-based controllers" as being successful as implied by the Examiner. It merely indicates that high-Q resonant circuits were experimentally validated, but makes no reference to successful "passivity-based controllers." Further, this section makes no enabling disclosure of a method

of designing a "passivity-based controller that extracts the . . . structural energy such that a resulting closed-loop response provides a desired noise reduction."

A complete reading of the Pota (2) reference leads the reader to the questions that are not answered by the Pota (2) reference, i.e. issues that were not researched and solved in the Pota (2) reference. One particular issue left open in Pota (2) factually supports the lack of enablement provided by Pota (2) regarding enablement of "designing a passivity-based controller that extracts the . . . structural energy such that a resulting closed-loop response provides a desired noise reduction." One issue Pota (2) expressly indicates that was not researched or answered and needs further research in Pota (2) is "What type of controllers, $A_i(s)$, guarantee closed loop stability?" Pota (2), Pg. 636, Col. 1, ¶ 4, Lines 1-2. The question itself in combination with the answer makes clear that Pota (2) does not enable designing such a "passivity-based controller." More particularly, Pota (2) states:

> The obvious choice of <u>passive controllers is not helpful.</u> From simulations it can be seen that a passive $A_i(s)$ <u>does not provide much damping</u>. Pota (2), Pg. 636, Col. 1, ¶ 4, Lines 2-5 (emphasis added).

Because the Pota (2) reference itself makes clear that its passive controllers it sampled are not to be selected and are not helpful for providing passive controllers for providing damping, Pota (2) does not enable designing such passivity-based controllers, as is required by claim 1 of the instant application.

Further, as indicated previously, in formulating an obviousness rejection over a combination of references, there must be some articulated reason for combining the references. However, one situation where there can be no reasonable reason to combine the references is when the references teach away from the combination." citing *In re Grasselli,* 713 F.2d 731, 743, 218 USPQ 769, 779 (Fed. Cir. 1983).

Assuming, *arguendo,* that Pota (2) in combination with Kelkar, Son and Pota enables the invention as claimed in claim 1, the Pota (2) reference still teaches away from the obviousness of the invention as claimed in claim 1. More particularly, Pota (2) teaches away from using a passive controller because a passive controller does not provide adequate dampening and therefore one of ordinary skill in the art would not look to designing "a passivity-based controller" to extract structural energy such that a resulting closed-loop response provides a desired noise reduction.

As indicated previously, Pota (2) expressly teaches away from this claimed invention as it states:

> The obvious choice of passive controllers is not helpful. From simulations it can be seen that a passive $A_i(s)$ does not provide much damping. Pota (2), Pg. 636, Col. 1, ¶ 4, Lines 2-5 (emphasis added).

Clearly, while it might have been an obvious choice to try a passive controller, Pota (2) expressly teaches away from such a controller and states that they do not provide adequate damping such that they should be used.

Further, while Pota cites to Pota (2) and states that "resonant controllers have proved effective in damping vibrations in flexible structure [citing to Pota (2)]," this statement makes no reference that resonant controllers are or provide a "passivity-based controller" or alternatively that passive resonant controllers provide effective damping. Thus, this statement in Pota does not rectify the fact that Pota (2) expressly teaches that "a passive $A_i(s)$ [controller] does not provide much damping."

In view of the lack of enablement and express teaching away from "designing a passivity-based controller that extracts . . . structural energy such that a resulting closed-loop response provides a desired noise reduction," Pota (2) fails to rectify the significant deficiencies in the combination of Kelkar, Son and Pota clearly articulated previously. As such, the obviousness rejection of claim 1, and the claims that depend therefrom, to wit, claims 10-15 cannot be maintained. The Appellants respectfully solicit the Board to overturn the rejection of claims 1 and 10-15 and indicate allowance thereof.

III. CONCLUSION: CLAIMS 1, 3-16 ARE IN CONDITION FOR ALLOWANCE

In view of the above, the Examiner has fully disregarded the fundamental principles of avoiding piecemeal prosecution, claim construction when determining definiteness of a claim, and generating a *prima facie* case of obviousness with regard to the rejections based on a modification of Kelkar in view of Son, Pota and Pota (2). Thus, claims 1 and 3-16 are definite with respect to the requirements of 35 U.S.C. § 112, second paragraph. Further, the proposed combination of references fails to enable, and in fact teaches away from the invention as claimed in claims 1 and 10-15.

The Appellants respectfully submit that claims 1, 3-16 are in condition for allowance. Consideration of this appeal, removal of the outstanding grounds of rejection and allowance of all rejected and objected to claims are respectfully solicited.

Further, as this Appeal Brief merely reinstates the previous appeal filed March 10, 2008, to which the Examiner responded by reopening prosecution, no fee for filing this Appeal Brief is owed pursuant to MPEP 1204.01. However, as the fee for filing an Appeal Brief has increased since filing the previous appeal on March 10, 2008, please charge Deposit Account No. 50-3505 the difference of those fees ($15.00) and any additional fee as may be required.

Respectfully submitted,

/Jeremy R. Bridge/

Jeremy R. Bridge, Reg. No. 61423
One of the Attorneys for Appellants
Reinhart Boerner Van Deuren P.C.
2215 Perrygreen Way
Rockford, Illinois 61107
Telephone (815) 633-5300
Fax (815) 654-5770

Date: October 21, 2008

CLAIMS APPENDIX

1. (Previously Presented) A method to design a feedback controller for extracting acoustic energy and structural energy in an acoustic enclosure comprising the steps of:

obtaining a continuous-time multi-input multi-output state-space mathematical model of the acoustic enclosure;

designing compensation to render the mathematical model passive in accordance with mathematical system theory if the mathematical model is not passive, thereby forming a compensated system that is passive;

checking passivity of the compensated system; and

designing a passivity-based controller that extracts the acoustic energy and the structural energy such that a resulting closed-loop response provides a desired noise reduction.

2. (Canceled)

3. (Previously Presented) The method of claim 1 wherein the step of obtaining a continuous-time multi-input multi-output state-space mathematical model of the acoustic enclosure comprises the step of obtaining a mathematical model having the form according to the equation

$$E\dot{x}(t) = Ax(t) + Bu(t) + Df(t)$$

where A, B, D, and E are matrices given by

$$E = \begin{bmatrix} E_{11} & 0 \\ E_{21} & E_{22} \end{bmatrix} \qquad A = \begin{bmatrix} A_{11} & 0 \\ 0 & A_{22} \end{bmatrix}$$

$$B = \frac{1}{h\rho_0 S_1}\begin{bmatrix} B_{11} \\ 0 \end{bmatrix} \qquad D = \frac{1}{h\rho_0}\begin{bmatrix} D_{11} \\ 0 \end{bmatrix}$$

where E_{11} = I and A_{11} = diag(A_{11}^{nm}) are square matrices of order p_1p_2, E_{22} = I and A_{22} =diag($A_{22}^{k_1k_2k_3}$) are square matrices of order $(l_1 + 1)(l_2 + 1)(l_3 + 1)$, B_{11} is a $p_1p_2\ x\ r$ matrix, D_{11} is a $p_1p_2\ x\ 1$ matrix where matrices E_{21}, A_{11}, A_{22}, B_{11}, and D_{11} are given by

$$E_{21} = -\frac{c_0^2 \rho_0}{V} \begin{bmatrix} 0 & 0 & \cdots 0 & 0 \\ 0 & \alpha_{00111} & \cdots 0 & \alpha_{001 p_1 p_2} \\ & \cdots & \cdots & \cdots \\ 0 & 0 & \cdots 0 & 0 \\ 0 & \alpha_{l_1 l_2 l_3 11} & \cdots 0 & \alpha_{l_1 l_2 l_3 p_1 p_2} \end{bmatrix}$$

$$A_{11}^{nm} = \begin{bmatrix} 0 & 1 \\ -\omega_{nm}^2 & -2\zeta_{nm}\omega_{nm} \end{bmatrix}$$

$$A_{22}^{k_1 k_2 k_3} = \begin{bmatrix} 0 & 1 \\ -\omega_{k_1 k_2 k_3}^2 & -2\zeta_{k_1 k_2 k_3}\omega_{k_1 k_2 k_3} \end{bmatrix}$$

$$B_{11} = \begin{bmatrix} 0 & \cdots & 0 \\ \phi_{11}(x_{11}, y_{11}) & \cdots & \phi_{11}(x_{1r}, y_{1r}) \\ \cdots & \cdots & \cdots \\ 0 & \cdots & 0 \\ \phi_{p_1 p_2}(x_{11}, y_{11}) & \cdots & \phi_{p_1 p_2}(x_{1r}, y_{1r}) \end{bmatrix}$$

$$D_{11} = \begin{bmatrix} 0 \\ \gamma_{11} \\ \cdots \\ 0 \\ \gamma_{p_1 p_2} \end{bmatrix}$$

where h is a thickness of the enclosure, ρ_0 is fluid density at equilibrium, S_1 is a boundary surface of the structure, c_0 is the sound speed, V is the volume of the enclosure, α 's are coupling coefficients describing the modal interaction between structural and acoustic modes, ω_{ij} denotes natural frequency related to ij-th mode for the structure, ω_{ijk} denotes the acoustical modal frequency for the ijk-th acoustic mode of the enclosure, ζ_{ij} is the damping of the ij-th structural mode shape, ζ_{ijk} is the damping of the ijk-th acoustical mode shape,

ϕ_{ij} is the ij-th mode shape of the enclosure structure, and γ_{ij} in matrix D_{11} indicate non-zero coefficients for the direct transmission terms which are functions of modal parameters.

4. (Previously Presented) The method of claim 1 wherein the step of designing a passivity-based controller includes designing a controller having a transfer function G(s) wherein

$$G(s) = Js^2 \sum_{k_1=0}^{l_1} \sum_{k_2=0}^{l_2} \sum_{k_3=0}^{l_3} \frac{\psi_{k_1k_2k_3}(x,y,z)}{s^2 + 2\zeta_{k_1k_2k_3}\omega_{k_1k_2k_3}s + \omega_{k_1k_2k_3}^2} [\sum_{n=1}^{p_1} \sum_{m=1}^{p_2} \frac{\alpha_{k_1k_2k_3nm}\phi_{nm}(x_{11},y_{11})}{s^2 + 2\zeta_{nm}\omega_{nm}s + \omega_{nm}^2}]$$

where $J = \frac{c_0^2\rho_0}{Vh\rho_p S_1}$, h is a thickness of the enclosure, ρ_0 is fluid density at equilibrium, S_1 is a boundary surface of the structure, c_0 is the sound speed, ρ_p is the density of the plate, $\psi_{k_1k_2k_3}(x,y,z)$ are normal modes of a non-homogeneous wave equation, $\omega_{k_1k_2k_3} = c_0\sqrt{\xi_{k_1}^2 + \xi_{k_2}^2 + \xi_{k_3}^2}$ with ξ_{k_1}, ξ_{k2}, and ξ_{k3} being modal coordinates, ζ_{ijk} is the damping of the ijk-th acoustical mode shape, α 's are coupling coefficients describing the modal interaction between structural and acoustic modes, and ζ_{ij} is the damping of the ij-th structural mode shape.

5. (Previously Presented) The method of claim 1 wherein the acoustic enclosure has a soft boundary and the step of designing a passivity-based controller includes designing a controller having a transfer function $G_{sb}(s)$ wherein

$$G_{sb}(s) = \sum_{i=1}^{l} \frac{\rho_0 s^2 c_0^2}{h\rho_p S_1} \cdot \frac{\Psi_i(r_0)}{s^2 + \rho_0 c_0^2 s D_{ii}(s) + c_0^2\beta_{ii}} \cdot [\sum_{n=1}^{p_1} \sum_{m=1}^{p_2} \frac{\eta_{inm}\phi_{nm}(x_{11},y_{11})}{s^2 + 2\zeta_{nm}\omega_{nm}s + \omega_{nm}^2}]$$

where Ψ_i denotes the eigenmode function for the acoustic pressure expression obtained using the assumed modes method, η_{inm} is the volume integral term consisting of integrand which is product of structural-acoustic eigenfunctions, ζ_{ij} is the damping of the ij-th structural mode shape, ρ_0 is fluid density at equilibrium, c_0 is the sound speed, S_1 is a boundary surface of the structure, h is a thickness of the enclosure, ρ_p is the density of the plate, ϕ_{ij} is the ij-th mode shape of the enclosure structure, and

$D_{ij}(s) = \int_S \frac{\Psi_j(s)\Psi_i(s)}{Z(r,s)} dS$, $\beta_{ij}(s) = \int_V \nabla\Psi_j(r)\nabla\Psi_i(r)dV$ where Z is the impedance.

6. (Previously Presented) The method of claim 1 wherein the step of designing compensation includes the step of designing a series passifier $C_s(s)$ according to

$C_s(s) \approx \begin{cases} \dot{x}_c = A_c x_c + B_c u \\ u' = C_c x_c + D_c u \end{cases}$ wherein Ac, Bc, Cc, and Dc are determined according to the steps comprising:

solving the equation $\begin{bmatrix} A^{**} & (*) & (*) \\ \hat{A} + A^T & YA + A^T Y & (*) \\ \hat{D}^T B^T - CX - D\hat{C} & \hat{B}^T - C & D^{**} \end{bmatrix} < 0$ to obtain

$X, Y, \hat{A}, \hat{B}, \hat{C}$, and $\hat{D}$;

constructing matrices M, N, and P such that

$$P\Pi_1 = \Pi_2 \text{ and } \Pi_1^T\Pi_2 = \begin{bmatrix} X & I \\ I & Y \end{bmatrix} \text{ where } XY + MN^T = I,\ \Pi_1 = \begin{bmatrix} X & I \\ M^T & 0 \end{bmatrix},$$

$\Pi_2 = \begin{bmatrix} I & Y \\ 0 & N^T \end{bmatrix}$, $P = \begin{bmatrix} Y & N \\ N^T & * \end{bmatrix}$; and

solving the equations $\hat{A} = YAX + YBC_cM^T + NA_cM^T$, $\hat{B} = YBD_c + NB_c$, $\hat{C} = C_cM^T$, and $\hat{D} = D_c$ in reverse order to obtain Ac, Bc, Cc, and Dc.

7. (Previously Presented) The method of claim 1 wherein the step of designing compensation comprises the step of designing a feedforward compensator $C_{ff}(s)$ according to

$C_{ff}(s) \approx \begin{cases} \dot{x}_c = A_c x_c + B_c u \\ y_2 = C_c x_c + D_c u \end{cases}$ wherein Ac, Bc, Cc, and Dc are determined according to the steps comprising:

solving the equation $\begin{bmatrix} AX + XA^T & (*) & (*) \\ \hat{A} + A^T & YA + A^T Y & (*) \\ B^T - CX - \hat{C} & B^T Y + \hat{B}^T - C & D^\perp \end{bmatrix} < 0$ where

$D^\perp = -(D + D^T + \hat{D} + \hat{D}^T)$ to obtain $X, Y, \hat{A}, \hat{B}, \hat{C},$ and $\hat{D}$;

constructing matrices M, N, and P such that

$$P\Pi_1 = \Pi_2 \text{ and } \Pi_2^T \widetilde{A} \Pi_1 = \begin{bmatrix} AX & A \\ YAX + NA_c M^T & YA \end{bmatrix} \text{ where } XY + MN^T = I,$$

$\Pi_1 = \begin{bmatrix} X & I \\ M^T & 0 \end{bmatrix}$, $\Pi_2 = \begin{bmatrix} I & Y \\ 0 & N^T \end{bmatrix}$, $P = \begin{bmatrix} Y & N \\ N^T & * \end{bmatrix}$; and

solving the equations $\hat{A} = YAX + NA_c M^T$, $\hat{B} = NB_c$, $\hat{C} = C_c M^T$, and $\hat{D} = D_c$ in reverse order to obtain *Ac*, *Bc*, *Cc*, and *Dc*.

8. (Previously Presented) A method to design a feedback controller for extracting acoustic energy and structural energy in an acoustic enclosure comprising the steps of:

obtaining a continuous-time multi-input multi-output state-space mathematical model of the acoustic enclosure;

designing compensation to render the mathematical model passive in accordance with mathematical system theory if the mathematical model is not passive, thereby forming a compensated system that is passive;

checking passivity of the compensated system;

designing a passivity-based controller that extracts at least one of acoustic energy or structural energy such that a resulting closed-loop response provides a desired noise reduction; and

wherein the step of designing compensation comprises the step of performing sensor blending if there are redundant sensors.

9. (Previously Presented) A method to design a feedback controller for extracting acoustic energy and structural energy in an acoustic enclosure comprising the steps of:

obtaining a continuous-time multi-input multi-output state-space mathematical model of the acoustic enclosure;

designing compensation to render the mathematical model passive in accordance with mathematical system theory if the mathematical model is not passive, thereby forming a compensated system that is passive;

checking passivity of the compensated system;

designing a passivity-based controller that extracts at least one of acoustic energy or structural energy such that a resulting closed-loop response provides a desired noise reduction; and

wherein the step of designing compensation comprises the step of performing control allocation if there are redundant actuators.

10. (Original) The method of claim 1 wherein the step of designing compensation to render the mathematical model passive comprises the steps of:

determining if a feedforward compensation will passify the system;

if a feedforward compensation will not passify the system:

designing a constant gain feedforward compensation to render the compensated system minimum-phase; and

rendering the compensated system positive-real by at least one of series compensation, sensor-blending and control allocation.

11. (Original) The method of claim 10 wherein the step of designing a passivity-based controller comprises the step of designing one of a dissipative linear-quadratic-Gaussian (LQG) type positive-real controller and a dissipative constant gain positive-real controller.

12. (Original) The method of claim 10 wherein the step of rendering the compensated system positive-real by at least one of series compensation, sensor-blending and control allocation comprises the step of rendering the compensated system positive-real by at least one of series compensation, feedback compensation, hybrid compensation, and sensor-blending and control allocation.

13. (Previously Presented) The method of claim 1 further comprising the step of redesigning the compensation if the passivity is not preserved.

14. (Previously Presented) The method of claim 1 further comprising the step of performing numerical simulations of the controller in the presence of a simulated broadband disturbance input.

15. (Original) The method of claim 14 further comprising the step of redesigning the controller if the closed-loop response is not satisfactory.

16. (Previously Presented) A method to design a feedback controller for extracting acoustic energy and structural energy in an acoustic enclosure comprising the steps of:

obtaining a continuous-time multi-input multi-output state-space mathematical model of the acoustic enclosure;

designing compensation to render the mathematical model passive in accordance with mathematical system theory if the mathematical model is not passive, thereby forming a compensated system that is passive;

checking passivity of the compensated system;

designing a passivity-based controller that extracts at least one of acoustic energy or structural energy such that a resulting closed-loop response provides a desired noise reduction; and

wherein the step of designing compensation comprises the steps of:

designing a constant gain feedforward compensation to render the compensated system minimum-phase; and

rendering the compensated system positive-real by one of sensor-blending and control allocation.

EVIDENCE APPENDIX

None

RELATED PROCEEDINGS APPENDIX

None.